HIGH ISOLATION DUAL POLARIZED ANTENNA SYSTEM USING DIPOLE RADIATING ELEMENTS

BACKGROUND OF THE INVENTION

Base stations used in wireless telecommunication systems have the capability to receive linear polarized electromagnetic signals. These signals are then processed by a receiver at the base station and fed into the telephone network. In practice, the same antenna which receives the signals can also be used to transmit signals if the transmitted signals are at different frequencies than the received signals.

A wireless telecommunication system suffers from the problem of multi-path fading. Diversity reception is often used to overcome the problem of severe multi-path fading. A diversity technique requires at least two signal paths that carry the same information but have uncorrelated multi-path fadings. Several types of diversity reception are used at base stations in the telecommunications industry including space diversity, direction diversity, polarization diversity, frequency diversity, and time diversity. A space diversity system receives signals from different points in space requiring two antennas separated by a significant distance. Polarization diversity uses orthogonal polarization to provide uncorrelated paths.

As is well-known in the art, the sense or direction of polarization of an antenna is measured from a fixed axis and can vary, depending upon system requirements. In particular, the sense of polarization can range from vertical polarization (0 degrees) to horizontal polarization (90 degrees). Currently, the most prevalent types of polarization used in systems are those which use vertical/horizontal and ±45°/−45° polarization ("slant 45°"). However, other angles of polarization can be used. If an antenna receives or transmits signals of two polarizations normally orthogonal, they are also known as dual polarized antennas.

An array of slant 45° polarized radiating elements is constructed using a linear or planar array of crossed-dipoles located above a ground plane. A crossed dipole is a pair of dipoles whose centers are co-located and whose axes are orthogonal. The axes of the dipoles are arranged such that they are parallel with the polarization sense required. In other words, the axes of each of the dipoles is positioned at some angle with respect to the vertical axis of the antenna array.

One problem associated with such a configuration is the interaction of the electromagnetic field of each crossed dipole with the fields of the other crossed dipoles and the surrounding structures which support and house the crossed dipoles. As is well known in the art, the individual electromagnetic fields surrounding the dipoles transfer energy to each other. This mutual coupling or leakage influences the correlation of the two orthogonally polarized signals; the amount of coupling is often referred to as "isolation." The isolation between orthogonally polarized signals is preferably −30 dB or less.

The visual impact of base station towers on communities has become a societal concern. It has become desirable to reduce the size of these towers and thereby lessen the visual impact of the towers on the community. The size and scale of the towers can be reduced by using base station towers with fewer antennas. This can be achieved if dual polarized antennas and polarization diversity are used. Such systems replace systems using space diversity which require pairs of vertically polarized antennas. Some studies indicate that, for urban environments, polarization diversity provides an equivalent signal quality as space diversity. With the majority of base station sites located in urban environments, it is likely that dual polarized antennas will be used in place of the conventional pairs of vertically polarized antennas.

SUMMARY OF THE INVENTION

It is a principle object of the invention to provide an antenna array comprised of dual polarized radiating elements which are used to receive signals for a polarization diversity receiver.

It is a further object of the invention to provide an antenna array where the radiating elements are comprised of crossed-dipole elements.

It is another object of the invention to provide an antenna array which improves isolation between the sum of one set of like-polarized signals and the sum of the orthogonal set of polarized signals.

It is yet another object of the invention to provide an antenna that minimizes the number of antennas required thereby providing an aesthetically pleasing structure that is of minimum size and scale.

It is still another object of the invention to provide an array of radiating elements where electrical "downtilt" is used.

These and other objects of the invention are provided by an improved antenna system comprising an array of radiating elements, the array having a length and placed on a ground plane and having a vertical axis along its length, the array comprising a plurality of dipole radiators, said radiators comprised of first and second crossed dipoles, said dipoles aligned at a predetermined angle with respect to said vertical axis, said radiating elements producing first electromagnetic fields; a plurality of supports, said supports perpendicular to said vertical axis and placed between selected of said plurality of dipole radiators; a plurality of metallic parasitic elements placed in a selected of said plurality of supports, said first electromagnetic fields exciting currents in said metallic parasitic elements, said currents creating second electromagnetic fields, said second electromagnetic fields canceling with said first electromagnetic fields.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 is a block diagram of the overall system which utilizes antennas according to principles of the present invention;

FIG. 2 shows a perspective view of an array of receivers together with the parasitic elements according to principles of the present invention;

FIG. 3 shows a top view of the array of FIG. 2 according to principles of the present invention;

FIG. 4 is an end view of the array of FIG. 2 according to principles of the present invention;

FIG. 5 is a top view showing de-coupling rods used as parasitic elements according to principles of the present invention;

FIG. 6 is an end view showing de-coupling rods used as parasitic elements according to principles of the present invention;

FIG. 7 is a top view showing de-coupling rods used as parasitic elements according to principles of the present invention; and

FIG. 8 is an end view showing de-coupling rods used as parasitic elements according to principles of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. **1**, a user with a cellular phone **4** transmits an electromagnetic signal to a base station **5**. The base station **5** comprises a plurality of antennas **6*a***, **6*b***, **6*c***, and **6*d*** connected to a platform **6*e***. As discussed below, each antenna comprises a plurality of crossed (co-located, orthogonal) dual dipole radiating elements. Alternatively, the antennas can be connected to a tower **7**. The platform **6*e*** is coupled to a tower **7** which elevates the antennas above surrounding buildings and other obstructions. The received signals pass over a plurality of transmission lines **8*a***, **8*b***, **8*c***, and **8*d*** to a base station processing system **3** which includes a diversity receiver **9**. From the base station processing system **3**, the processed signals are transmitted over land phone lines and into the telephone network using equipment and techniques which are well known to those skilled in the art.

Referring now to FIGS. **2–4**, an array (antenna) **10** of crossed, dual-polarized dipole radiating elements **11*a***, **11*b***, **11*c***, and **11*d*** are connected to a ground plane **12**. The composition and dimensions of the radiating elements **11*a***, **11*b***, **11*c***, and **11*d*** and the ground plane **12** determine the radiation characteristics, beam width, and the impedance of the radiating elements. Preferably, the radiating elements **11*a***, **11*b***, **11*c***, and **11*d*** and the ground plane **12** are composed of some metal such as aluminum. However, other metals can be used to construct the radiating elements and the ground plane **12** such as copper or brass.

It will be understood by those skilled in the art that the gain of the antenna is proportional to the number of spaced radiating elements present in the array. In other words, increasing the number of radiating elements in the array increases the gain while decreasing the number of radiating elements decreases the antenna's gain. Therefore, although only four radiating elements are shown, the number of radiating elements can be increased to any number to increase the gain. Conversely, the number of radiating elements can be reduced as required thereby reducing the gain.

The radiating elements **11*a***, **11*b***, **11*c***, and **11*d*** transmit and receive electromagnetic signal transmissions and are comprised of pairs of dipoles **14*a*** and **14*b***, **16*a*** and **16*b***, **18*a*** and **18*b*** and **20*a*** and **20*b***, respectively. The dipoles comprising the radiating elements **11*a***, **11*b***, **11*c***, and **11*d*** are crossed and configured with 45 degree slant angles (with respect to the axis of the array **13**). That is, the axes of the dipoles are arranged such that they are parallel with the polarization sense required. As shown, the slant angles $+\alpha$ and $-\alpha$ are +45 degrees and −45 degrees, respectively. Although shown with slant angles of +45 degrees and −45 degrees, it will be understood by those skilled in the art that these angles can be varied to optimize the performance of the antenna. Moreover, each angle need not be identical in magnitude. For example, $+\alpha$ and $-\alpha$ can be +30 degrees and −60 degrees, respectively.

Each of the radiating elements **11*a***, **11*b***, **11*c***, and **11*d*** receive signals having polarizations of +45 degrees and −45 degrees. That is, one dipole in the radiating element receives signals having polarizations of +45 degrees while the other dipole receives signals with polarizations of −45 degrees. The received signals from parallel dipoles, **14*a***, **16*a***, **18*a***, **20*a*** or **14*b***, **16*b***, **18*b***, and **20*b***, are combined using a feed network (not shown) for each polarization. The feed network is composed of coaxial, microstrip, stripline, or other transmission line structures. The two combined signals are fed to a diversity receiver which chooses the strongest amongst these two signals for further processing. Each of the radiating elements **11*a***, **11*b***, **11*c***, and **11*d*** can also act as a transmitter provided that the transmitted signal is at a different frequency than the received signal.

A parasitic element **22** is placed on a support **24**. In order to be non-conducting, the support is comprised of polyethylene foam. However, other suitable non-conducting materials such as other non-conducting plastics or foams can be substituted for polyethylene foam and used for construction of the support **24**. The support **24** is first formed and attached to the back plane **12**. A groove is then cut into the support **24** into which the parasitic element **22** is inserted.

In order for currents to be induced, the parasitic element **22** is formed of metal. This metal is preferably aluminum, although other metals such as copper or brass can also be used. A primary electromagnetic wave or field incident upon the array structure induces currents on the surfaces of the crossed dipoles of each of the radiating elements of the array, the parasitic elements, and the surrounding metal structure. These induced currents create a weaker secondary electromagnetic field which will combine with the primary electromagnetic field. A state of equilibrium will occur such that the final electromagnetic field is different from the primary electromagnetic field. The dimensions and positions of the parasitic elements are a factor in determining the final field. In other words, the improved isolation of the present invention is achieved by currents excited on the parasitic elements which re-radiate energy that cancels the energy which couples from one polarization to the other causing the isolation to be at a minimum.

The parasitic elements are placed halfway between the crossed dipole radiating elements of the array and are perpendicular to the axis **13** of the array. However, parasitic elements are not necessarily placed in between every element of the array. A network analyzer is used to determine the optimum number and positioning of the elements. In particular, the network analyzer is employed such that the isolation of any given configuration of radiating elements and parasitic elements can be measured. The length of the parasitic elements controls the magnitude of the current produced. For example, with the length at approximately one-half a wavelength, the maximum amount of current is produced. Thus, the performance of the system can also be optimized by changing the length of some or all of the parasitic elements.

Positioning the parasitic element above the top of the crossed dipoles has been found to optimize isolation for this array configuration. However, the height of placement of the parasitic element can vary depending on the array configuration.

The parasitic elements are situated so as to cause no undue side effects such as degradation of the return loss (VSWR) nor do the parasitic elements unduly disturb the normal array radiation patterns. It has been found that optimum antenna performance occurs when the parasitic elements are placed parallel to or perpendicular to the vertical axis of the array. Placing the parasitic elements at other angles with respect to the vertical axis of the array has been found to detrimentally affect antenna performance. As discussed above, a network analyzer is used to determine when isolation improves and radiation patterns measured confirm to pattern performance.

In an illustrative embodiment of the configuration of FIG. **2**, four crossed-dipole antennas were placed on a ground plane 480 mm long by 150 mm wide to operate in the PCS/N band of frequencies which is 1710–1990 MHz. The vertical